Accessibility to Metro of Affordable and Commercial Housing Complexes in Shanghai

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Master of Science in Urban Planning

by

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Abstract

This thesis has three research questions. The first one is whether *Affordable Housing Planning and Management Regulation* (“the regulation”) in 2008 has been followed that affordable housing should be built within a 15-minute walk from metro stations. The second question is whether there are significant differences between affordable and commercial housing complexes in metro accessibility. The third question is whether housing type is an important factor in accessibility.

This study is based on a mixed-method research design: statistical, quantitative analysis and combined with qualitative analysis of observations. The results are then used to make policy suggestions towards equitable and adaptive locations of affordable housing and metro stations.

The study shows that most affordable housing complexes have not followed the regulation in 2008 because most of them were not built within a 15-minute walk from metro stations. Additionally, commercial housing complexes have better accessibility to metro than affordable ones in two aspects: the level of convenience from a certain residential complex to surrounding metro stations, and the level of convenience from surrounding metro stations to points of interest (POI). Although housing price and distance to city center are also important, housing type is a more significant factor in metro accessibility. The study recommends the planning department to combine transportation and affordable housing planning, create more POI in suburban areas, and connect suburban areas with metro.

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Table of Contents

List of Tables

List of Figures

Chapter 1. Introduction

Affordable housing is an important part of social welfare and a main way to meet the demands of low-income group for dwelling (Wang, Tang, Jin, and Zhou, 2010). In China, affordable housing is defined as a housing system including economic and comfortable housing, low rent housing, public rental housing and resettlement housing.

Economic and comfortable housing is designed to be available to low-income households to encourage home ownership. Low rent housing is provided by the government to low- and extremely low-income urban households. Public rental housing is designed for a larger scope of low-income populations than low rent housing, which is open for both local and non-local populations. Resettlement housing is especially designed for people who previously lived in the area that is now going to be redeveloped by the government (Yu, 2016). In contrast, commercial housing is provided by the market to meet the needs and demands of middle- to high-income families (Wang 2011).

In the last 20 years, housing prices have skyrocketed in Chinese cities, with the national average housing price increasing by 1400% (Property Time, 2018). In big cities like Shanghai, a modest apartment can cost multiple millions of yuan to purchase, making housing affordability a top concern of most low-income households (Huang, 2013). In response to the great demands for housing in urban area, both central government and municipals have been working on securing housing affordability by increasing affordable housing provision (Yu, 2016). Providing affordable housing is a tremendous task faced by all countries (Rosen & Ross, 2000). This is especially true in

China, not only because of the largest population in the world, but also because its housing sector has evolved from a government-dominated welfare system to a market-driven one in little more than a decade (Chiu, 2001; Zhao & Bourassa, 2003).

In 1979, China initiated Housing Reform to expand private property rights in housing and to promote home ownership through the commercialization and privatization of urban public housing (Man, 2011). Then in 1998, the Department of Construction promulgated *The Notice of Deepening Urban Housing Reform*, marked the start of the affordable housing program in China (Shi, Chen, and Wang, 2016). By the end of 2017, nearly 2.2 million affordable housing units have been built to solve the living difficulty of low-income families in the country (Zhang, 2017).

However, affordable housing may lose its affordability if it does not provide efficient public transportation (Hao, 2010). Unlike general housing, affordable housing possesses the special meaning of security, thus more importance should be attached to the construction of public transportation for affordable housing (Balachandran, 2018). In Shanghai, affordable housing residents on average spend one tenth of their income and more than one hour on daily transportation, which they cannot afford in the long run (Ni, 2012). Although affordable housing has benefits of lower housing prices, it would lose its equity if public transportation facilities of affordable housing significantly differ from that of commercial housing (Xu, 2008). Since there is a growing demand for public transportation equity, the purpose of the study is to see whether there are differences in metro accessibility between affordable and commercial housing.

This study has three objectives. First of all, this thesis will examine how accessible metro is to affordable housing complexes and whether affordable housing built after 2008 has followed *Affordable Housing Planning and Management Regulation* (the regulation) in 2008 that affordable housing should be built along metro lines and within a radius of 10 to 15 minutes' walk from metro stations.

The second research question is whether there is a significant difference in metro accessibility between affordable and commercial housing complexes. The comparison should include two factors: the level of convenience from a certain residential complex to surrounding metro stations, and the level of convenience from surrounding metro stations to points of interest (POI).

The third question is whether housing type (affordable housing or not) is an important factor in metro accessibility among different factors. Housing type should be compared to other factors such as housing price and the distance to city center.

This thesis will provide greater understanding of whether affordable housing and commercial housing have similar levels of metro accessibility or not. So far, few systematic analyses have been conducted on the public transportation facilities around affordable housing. I hope this study provides an example in utilizing statistical data to assess metro accessibility for affordable housing. The results could be useful for planners, housing officials, and transportation officials who make decisions in affordable housing planning.

Chapter 2. Background

2.1 Affordable housing in Shanghai

Shanghai, as the largest city and the leading industrial center in China, is sufficient to be an important case study of housing affordability. Shanghai has always been the most expensive housing market in China, whose housing price is comparable to the most expensive cities' in the world (Chen and Hao, 2010). In 2018, Shanghai's 24 million residents constitute approximately only 1.7 per cent of China's total population. However, its housing market of 51 trillion yuan accounts for 20 percent of the country's total housing market capitalization (Sohu, 2018). Therefore, affordable housing is essential for low-income people to survive with high housing prices in Shanghai.

Affordable housing system in Shanghai started from the late 1980s, and went through three stages (Yang, 2013). The first stage is solving housing difficulties (1987-1999); the second stage is low rent housing and resettlement housing (2000-2008); and third stage is developing four types of affordable housing (2009-present).

Shanghai is consistent with the country in the affordable housing system, which includes economic and comfort housing, low rent housing, public rental housing and resettlement housing (table 1). The rental and housing price of economic and comfort housing is a little higher than other types of affordable housing, but the physical condition of the housing is better. Only locally registered population (people that have Shanghai "hukou") are eligible to apply for economic and comfort housing. Low rent housing is provided for the low- and extremely low-income people who have Shanghai "hukou", and they can get extra housing subsidies from the government. Public rental housing is open for both local and non-local populations. Resettlement housing, only for locals as well, is especially designed for people who previously lived in the area that is now going to be redeveloped by the government (Yu, 2016).

Table 1. Four Types of affordable housing in Shanghai

Type	Home Ownership	General Housing Price or Rental	Targeted Group		Benefits
			Economic Status	Residence Status	
Low rent housing	Rent (can own the unit if the renter has lived there for over 10 years)	Lowest	Low- and extremely low-income people	Shanghai "hukou" holder (registered Shanghai residents)	Extra subsidies provided by the government
Economic comfortable housing	Own	Highest	Varied in different cities	Shanghai "hukou" holder	
Public rental housing	Rent (can own the unit if the renter has lived there for over 10 years)	Median	Varied in different cities	Both locally registered and nonlocal population	
Resettlement housing	Mixed (Own or rent)	Median	Varied in different cities	Shanghai "hukou" holder	

Source: Yu, 2016

By the end of 2018, the total numbers of low rent housing, economic and comfortable housing, and public rental housing in Shanghai reached 127,000, 120,000 and 126,000 units respectively. Currently, there are about 434 affordable housing residential complexes in Shanghai. In 2019, Shanghai plans to build 60,000 affordable housing units (Eastern Network, 2019).

In Shanghai's Thirteenth Five-Year-Plan (2016-2020) issued by the government, affordable housing construction was emphasized with the goal of increasing about 550,000 affordable apartments and 1,800 hectares construction land by 2020.

2.2 Importance of metro to affordable housing residents

Public transportation, as one of the main focuses in affordable housing construction, relates not only to the living quality of affordable housing residents but also to the sustainable development of affordable housing system (Wang, Tang, Jin, and Zhou, 2010).

Transportation is an essential part of civil life. According to Shanghai Statistics Bureau, the per capita expenditure on transportation is 4,058 yuan in 2018, which is more than 10% of the total consumption expenditure. Furthermore, public transportation is especially important for affordable housing residents because most of affordable housing residents cannot afford a car. By 2017, the car ownership ratio in Shanghai is 14.9 cars per one hundred residents (Mao, 2018). It is also estimated that 61.1% of families in Shanghai do not own a car (Jie, 2018). Considering that affordable housing residents have a disposable income lower than 80% of the average level, most affordable housing families mainly rely on public transportation in their daily life.

Moreover, metro plays an important role in the public transportation of Shanghai. It accounts for 53% of passenger flow in the public transportation, which is the highest in China (Wen, 2017). As is shown in Figure 1, Shanghai Metro is an extensive metro system with the longest route length in the world (CityMetric, 2018). By 2018, it has 16 lines, 389 stations, and a total length of 672 kilometers. Besides, it has an average passenger flow of 9.6 million every day (Wang, 2018).

In 2008, the Shanghai government promulgated *Affordable Housing Planning and Management Regulation*, which pointed out that affordable housing projects should be located in areas with as much public transportation as possible, including metro and buses. Also, priority should be given to the perfection of metro or subway around affordable housing in regional transportation planning (Niu, 2009). More importantly, affordable housing should be built along metro lines and within a radius of 10 to 15 minutes' walk from metro stations (Chen, 2011).

2.3 Current situation of affordable housing in Shanghai

Most affordable housing complexes in Shanghai are located outside of the outer ring, leading to the higher living costs for affordable residents (Peng, 2008). Generally speaking, suburban area in Shanghai is defined as the areas outside the central districts.

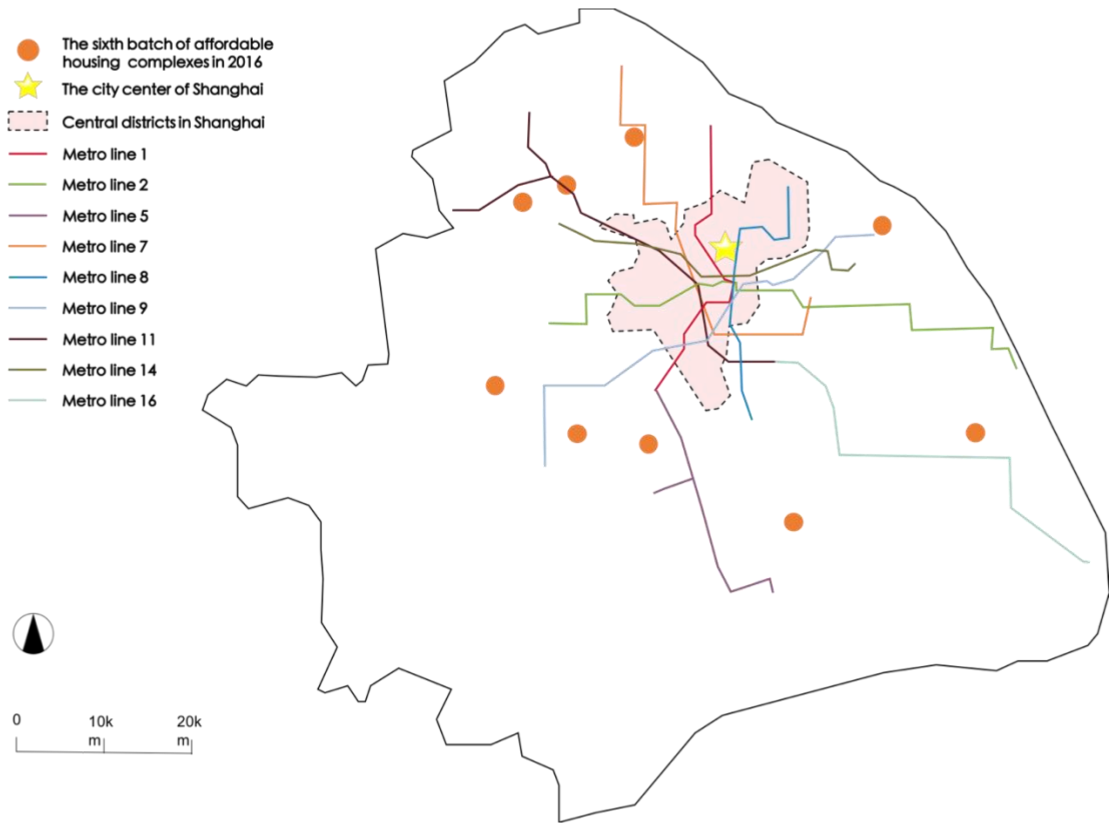

Figure 1. Location of the sixth batch of affordable housing in Shanghai

Source: Shanghai Affordable housing website. http://bzf.ehousee.com/xmqk/xmqk.html

Take the sixth batch of 2016 affordable housing projects for an example, we can see that the affordable housing complexes are not located in the central districts of Shanghai (Figure 1). That is to say, all affordable housing projects in this batch are built in the suburban area of Shanghai, which is also common in other batches.

Studies show that affordable housing residents are not satisfied with public transportation (Xu, 2008; Hao, 2010) and that the average walking time from affordable housing complexes to metro stations is 25 minutes (Wang and Shi, 2014).

Since metro is the main and most efficient public transportation in Shanghai (Shen, 2016), this thesis will examine how accessible metro is to affordable housing complexes and whether there is significant difference in metro accessibility between affordable and commercial housing complexes.

Chapter 3. Literature Review

3.1 Location and transportation of affordable housing

Many scholars believe that affordable housing projects in China are located in suburban areas and the transportation network is insufficient. Though the study on affordable housing in 21 major cities of China, Ding (2014) concludes that most affordable housing complexes are located in remote areas and the public transportation is poor, which cause high transportation costs for affordable housing residents. The inconvenient location and transportation lead to a high vacancy rate of affordable housing, which is common in cities such as Guangzhou, Shanghai, Beijing and Nanjing.

One reason is that the local governments are driven by land revenues, so they locate affordable housing projects in suburbs with the minimum loss of revenue (Zhang and Liu 2014). Therefore, lower land prices in suburban areas are more suitable for affordable housing. Another reason is that the large scale and fast occupancy rate of affordable housing is beneficial to the rapid maturity and long-term development of the suburban areas (Chen 2011).

For affordable housing in Shanghai, Wang and Shi (2014) find that all affordable housing bases and most large affordable housing communities in Shanghai are located in suburban areas and do not have efficient transportation network.

3.2 Public transportation equity and accessibility

3.2.1 Public transportation equity

Public transportation equity means that public transportation favors economically and socially disadvantaged groups in order to compensating for overall inequities (Rawls 1971). Many scholars believe that there is a strong need for public transportation, especially for affordable housing residents. Income is closely related to public transportation need, that is, a reduction in household income leads to a reduction in vehicle ownership (Dargay, 2001). Paulley et al. (2006) finds that lower income families own fewer vehicles and are more reliant on public transport. Therefore, many low-income households attempt to locate near transit, where it is available (Ong, 1996). These literatures suggest that affordable housing residents should have equal or even higher level of accessibility to public transportation than commercial housing residents.

3.2.2 Public transportation accessibility

The most common approaches define accessibility based on travel times or distance from public resources (Joseph and Phillips 1984; Talen 1998; Witten et al. 2003). Accessibility essentially describes an individual's ability to reach all kinds of opportunities, including desired goods, services, activities and destinations (Litman, 2003).

As for public transportation accessibility, the idea is emphasized in Hillman and Pool (1997) that the public transportation accessibility essentially addresses local accessibility, but indirectly also incorporates network accessibility by using route and frequency data. Local accessibility is the accessibility of a particular location to a public transportation system while network accessibility is the accessibility of locations in a city by the public transportation system. A study by Litman (2008) attempts to incorporate both aspects by defining public transportation accessibility as the quality and ease of transit service at a particular location. The thesis will use local accessibility in measuring public transportation accessibility.

3.2.3 Measurements of transportation accessibility

Many researchers use only one of the simple methods to measure transportation accessibility. The simplest and most applicable way to determine accessibility might be measuring geographic distance by straight-line distance or shortest network distance (Apparicio and Seguin 2006; Zhang, 2016). Similarly, accessibility is frequently measured by walk time proximity (Handy and Niemeier, 1997). Davidson (1980) argues that the most accurate way to measure accessibility, such as network analysis, is more suitable. Besides, it is common to measure service quality in terms of the number of routes in an area or frequencies at specific stops (Bowman and Turnquist, 1981; Sanchez et al., 2004; Wen, 2010). Moreover, many more accessibility measures exist that incorporate land use, temporal and individual characteristics (Geurs and Van, 2004).

However, some other scholars use Accessibility Index to measure transportation accessibility, which combines two or more simple methods. Shah (2016) uses Public Transport Accessibility Level (PTAL) in measuring public transport accessibility level in India, which is also adopted by UK, U.S., the Netherlands, Australia, and New Zealand (Joyce and Dunn, 2010). With PTAL, Accessibility Index is calculated as $\mathrm{AI} = \sum \frac{1}{D1} +$

$0.5 \times \sum \frac{1}{D2}$, where D1 is the distance of points of interest (POI) in main study area and D2 is the distance of POI in secondary study area.

Table 2. Summary of different accessibility measurements

Methods	Advantages	Disadvantages	Use
Straight-line distance	Direct and simple	Only consider one station	Local accessibility
Shortest network distance	Closer to the reality than Straight-line distance	Only consider one station	Local accessibility
Number of routes/stations and frequency of service	Consider multiple stations	Does not consider proximity	Local accessibility
Temporal and individual characteristics	Close to the reality	Need a large sample and a long research duration	Local accessibility, network accessibility
Accessibility Index PTAL	Consider multiple stations and proximity	Difficult in calculation	Local accessibility
Accessibility Index LUPTAI	Consider land use and multiple stations	Accessibility index values are subjectively assigned	Network accessibility
Accessibility Index TTSAT	Close to the reality with customized travel time	Need a large sample for the study	Local accessibility

Another popular method is the Land Use and Public Transport Accessibility Index (LUPTAI), which seeks to measure how easy it is to access common destination by public transport (Pitot et al. 2005). The LUPTAI method has five steps and the Accessibility Index values are assigned for different land parcels in regard to particular destinations in the fifth step. Besides, Time-Based Transit Service Area Tool (TTSAT) is a new approach to mapping transit accessibility by incorporating total trip travel time into the transit service area maps it generates. To be detailed, TTSAT integrates all segments of a complete, door-to-door transit trip into the trip time calculations. Its users can customize the time-based transit service area (TTSA) maps they generate by specifying details of passengers' expected travel behavior, such as walking speed or the maximum time they are willing to spend going to and from public transport stops (Cheng and Agrawal 2010).

A common practice in transportation planning is to assume that people are served by the transportation tool if they are within a 10-minute walk (or 1000 m) of a metro station (Murray 2001, Peng et al. 1997, Ramirez and Seneviratne 1996). Also, Zhang (2007) in the section on "Dockized District" discusses the issue of choosing an analytical cat chment area of 1000 m from the station. Pitot et al. (2005) agree with the common use of 10min walk to metro stations, and regard 20min walk (or 2000 m) is applied as the maximum walking distance for the metro accessibility measurement, where walking distances at both ends of the trip are considered in the methodology. Although most scholars agree on the 10-minute walk for metro accessibility measurements, some use 800m instead of 1000m for the distance of 10-minute walk. According to a study by Echo Credits, an average person's walking speed is 1 km or 0.6 miles per 10 minutes. Therefore, in this thesis I assume that the distance of a 10-minute walk equals to 1000 meters.

3.2.4 Factors affecting transportation accessibility

There are many different influential factors of transportation accessibility according to different researchers. The common factors influencing accessibility are housing/and price and the distance to CBD/city center. Savigear (1967) suggests that accessibility can include distance to central business districts (CBD). Peng (2010) regards location, natural conditions, land prices and urban planning also important. Zhang (2011) believes influential factors include housing price, distance to city center, distance to hospital, distance to primary school, distance to green space, and so on.

3.2.5 Limitation of literatures

One limitation is that literatures mainly focus on measuring local accessibility of transportation. Few literatures consider both local accessibility and network accessibility of public transportation. Another limitation is that there are not many literatures on the factors of metro accessibility, which increases the difficulty of selecting independent variables for the regression analysis.

Chapter 4. Methodology

This study is based on a mixed-method research design. The first part is composed of a statistical, quantitative analysis and the second part is observation. The results will then be used to make policy suggestions towards equitable and adaptive locations of affordable housing and metro stations.

Additionally, following methods will be used according to literature review. The Accessibility Index will be appropriately adapted from Public Transport Accessibility Level (PTAL) method, which will combine shortest network distance and number of routes to measure local accessibility. For accessibility measurement, the walking distance of 1000 m to 2000 m is chosen for the network analysis.

4.1 Regression analysis on Accessibility Index

This test will be a multiple regression in order to analyze the correlation (or lack thereof) between metro accessibility and housing type (whether it is affordable housing or not). First of all, a power test will be conducted to ensure a sufficient sample size. Then, the correlation of variables will be checked to eliminate collinearity. Next, several models will be run in the regression to select a most suitable model. In the end, the regression will be interpreted and evaluated.

4.1.1 Hypothesis

Based on literature reviews, this thesis has the following hypotheses:

- affordable housing complexes are more likely to have a lower metro accessibility than commercial housing complexes;

- the higher housing price a residential complex has, the more likely it will have a higher metro accessibility;
- the longer it takes to travel from a residential complex to the city center with public transportation, the more likely it will have a lower metro accessibility;
- the earlier built year a residential complex has, the more likely it will have a higher metro accessibility.

4.1.2 Sample selection

The thesis uses random sampling to select residential complexes. Currently, there are about 434 affordable housing complexes and 52,419 commercial housing complexes in Shanghai, which can be downloaded from Shanghai Housing Bureau Website. With the random number function in Excel, the thesis randomly selects 50 complexes from both of the populations.

4.1.3 Variable selection

In the regression, independent variables include Housing Price (P), Housing Type (H), Built Year (Y) and Travel Time to city center (T). Housing Price is the average housing price of a residential complex in February 2019. The unit of housing price is yuan/ square meter. For Housing Type, affordable housing is recorded as 1 and commercial housing is recorded as 0. Built Year means the year that a residential complex was built. Travel Time is the shortest time of traveling on any public transportation from a residential complex to the city center (People's Square in Shanghai). It is assumed that the location of a residential complex is the geometric centroid of the complex. The unit of travel time is minute.

The dependent variable is the metro Accessibility Index (A) that measures the local accessibility from residential complexes to metro stations. The study uses walking distance instead of direct distance in the calculation. According to literature review, the Accessibility Index can be expressed as $\mathrm{A} = \sum \frac{1}{D1000} + 0.67 \times \sum \frac{1}{D1500} + 0.5 \times \sum \frac{1}{D2000}$, where D_{1000}, D_{1500} and D_{2000} respectively mean the walking distance to metro stations within 1000 m, 1500 m and 2000 m from residential complexes. Therefore, the closer of the metro stations, the higher of the Accessibility Index will be. Also, if there are more than one metro station within the service area, the Accessibility Index will be higher. The coefficients of 0.67 and 0.5 mean that the metro stations within walking distances of 1000m-1500m and 1500m-2000m are less attractive to people, so the Accessibility Index is weighed. If there is no metro station within a 2000 m service area, then the Accessibility Index is zero.

It is assumed that people will go to the nearest metro station from a residential complex, if surrounding stations are on the same metro line. Therefore, for a certain metro line, only the nearest metro station will be included in the calculation. However, if there are several metro lines, the nearest station on each line will be included in the calculation. For a metro station containing several lines, it can be calculated multiple times as long as it is the nearest station on a certain metro line.

4.1.4 Data collection

The study will use the data of housing and metro stations to analyze whether there is a significant relationship between metro accessibility and housing types in Shanghai. First of all, affordable housing data and commercial housing data can be derived from Shanghai Housing Bureau, which provides locations of all residential complexes in Shanghai. The data of housing price and built year can be found on Anjuke's website, a big real estate company in China. Secondly, travel time of public transportation to the city center can be measured on Baidu Map. Travel time is measured at 8 am on work days. If there are several ways of traveling from a certain residential complex to the city center, the one with the shortest travel time will be chosen. Thirdly, metro station data are derived from the Shanghai Metro, which provides the location of each line and each station. Additionally, points of interest in Shanghai can be obtained from Baidu Map.

4.2 Observation of accessibility quality

Beside the above analysis on the quantity of accessibility, observation is aimed to analyze the quality of accessibility, which means how easy it is to get from a given metro station to points of interest (POI). Accessibility Index analysis and Accessibility Quality analysis do not overlap. The former concentrates on the analysis from a residential complex to its surrounding metro stations. The latter focuses on the analysis from surrounding metro stations to POI. Generally, people will be attracted by points of interest, which provide job, shopping and entertainment opportunities, etc. Therefore, the more points of interest around one metro station (the higher POI value a station has), the more likely people want to get to that station.

This study will select three affordable housing complexes for observation, which have high, mean and low values in Accessibility Index. Then, three commercial housing complexes will be paired with affordable housing complexes mainly according to the Accessibility Index value. That is, affordable and commercial housing complexes in one pair have the same or similar Accessibility Index values. It is calculated how many stations and travel time a residential complex will use to get to the nearest station with high POI value. In the end, the quality of metro accessibility will be compared between affordable and commercial residential complexes in the observation.

Chapter 5. Findings

5.1 Descriptive statistics of accessibility and other variables

Variables will be analyzed in descriptive statistics, including the analysis of average values, ranges, and distributions. The purpose of the descriptive statistics is to translate the statistics numbers into useful conclusions. By doing this, there will be a preliminary comparison of metro accessibility between affordable and commercial residential complexes.

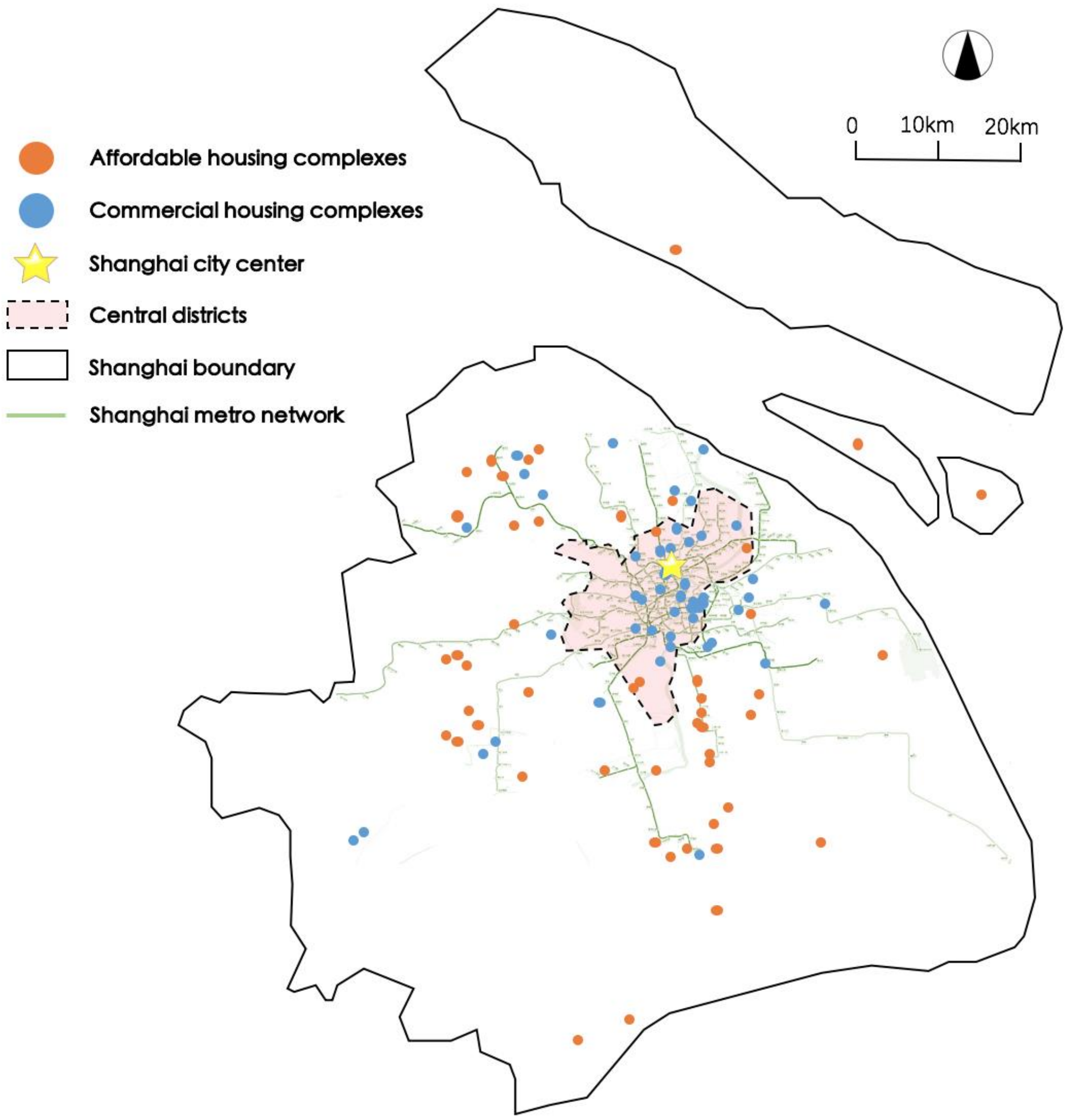

Figure 2. Location of complex samples and metro lines in Shanghai

As is shown in Figure 2, there are 50 samples of affordable housing complexes and commercial housing complexes respectively. These samples are all randomly selected. Most of 50 affordable housing complexes are located out of the central districts while commercial housing complexes are concentrated in the central area.

5.1.1 Metro stations and lines

Compared with affordable housing complexes, commercial housing complexes in the study have much more metro stations and lines within a 2,000-meter walking distance.

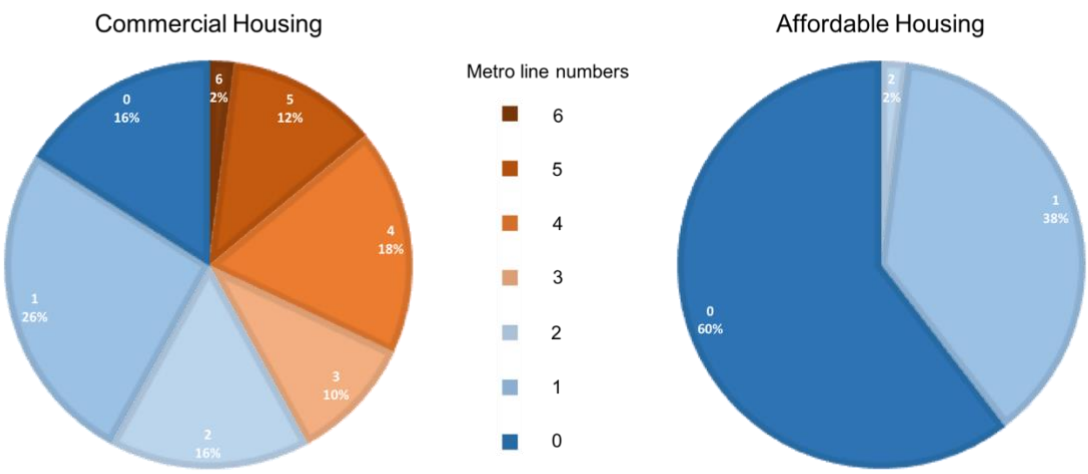

Figure 3. Metro comparison between affordable and commercial complexes

Among 50 commercial housing complexes, 42 of them have at least one metro station within a 2,000-meter walking distance from the residential complex. Among these 42 complexes, the average walking distance to the nearest metro station is 680 meters. The shortest walking distance to a metro station is 40 meters. For commercial housing complexes, there are 2.32 metro lines on average within the 2,000-meter walking distance. The maximum number of metro lines within the 2,000-meter walking distance is 6.

In contrast, among 50 affordable housing complexes, only 19 of them have at least one metro station within a 2,000-meter walking distance from the residential complex. Among these 19 complexes, the average walking distance to a nearest metro station is 1271 meters. The nearest walking distance to a metro station is 250 meters. For affordable housing complexes, there are 0.4 metro lines on average within the 2,000-meter walking distance. The maximum number of metro lines within the 2,000-meter walking distance is 2, which is the only affordable housing sample that has two metro lines.

Table 3. The comparisons of affordable housing and commercial housing

Within 2000m walking distance	Affordable housing	Commercial housing
Percentage of complexes that have stations	38%	84%
Average metro lines	0.4	2.32
Average distance to a nearest station (m)	1271	680

5.1.2 Descriptive Statistics of regression variables

There are 100 complexes in the regression, half of which are affordable housing complexes. We can see from the summary data that more than 1/4 of the complexes have the Accessibility Index (A) of 0, which means that there are no metro stations within a 2000-meter service area around that residential complex sample. The maximum Accessibility Index is 0.54.

Table 4. Descriptive statistics for each variable

	Housing Type	Accessibility Index	Built Year	Travel Time	Housing Price
Min.	0.0	0.0000000	1980	5.00	5772
1st Qu.	0.0	0.0000000	2004	47.75	24672
Median	0.5	0.0004467	2010	74.00	35836
Mean	0.5	0.0026168	2009	76.97	43921
3rd Qu.	1.0	0.0028781	2015	99.25	60694
Max.	1.0	0.0538378	2018	254.00	112932

For built year (Y), the median and mean built year of residential complexes are 2010 and 2009. Most of the residential complexes in the sample were built after 1995 and the most recent sample was built in 2018. The distribution of built years is not normal distribution because the kurtosis is 0.93 and skewness is -0.91. There were relatively fewer complexes built in 2008 and 2009, which might be caused by the global financial crisis in 2008. Besides, only 7 of 47 complexes (built after 2008) are within 15 minutes' walk to metro stations.

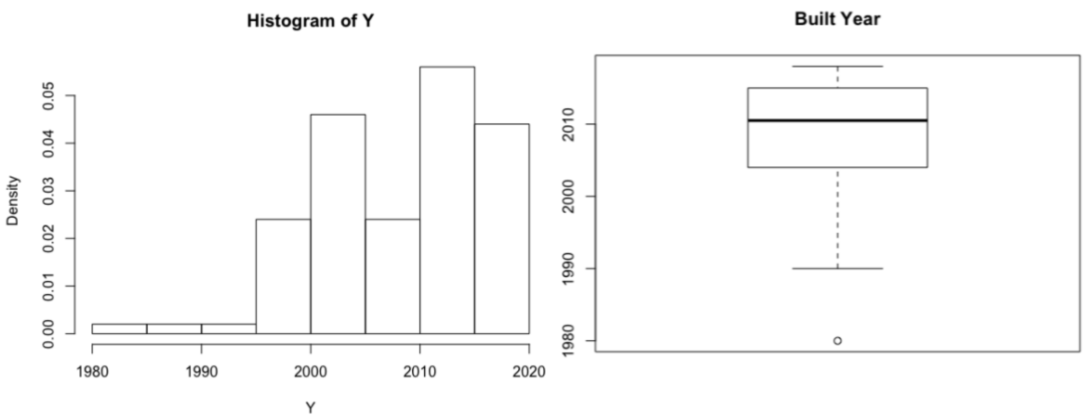

Figure 4. Descriptive statistics of built year

For travel time (T), the median and mean time of traveling from one residential complex to the city center is around 75 minutes. That is, people spend 75 minutes on average to travel from their residential complexes to the city center with public transportation, at 8 am on work days. Three quarters of the complexes have the travel time of less than 100 minutes. However, travel time is highly varied with a minimum of 5 minutes and a maximum of 254 minutes. The distribution of travel time is not normal distribution because the kurtosis is 2.83 and skewness is 1.17.

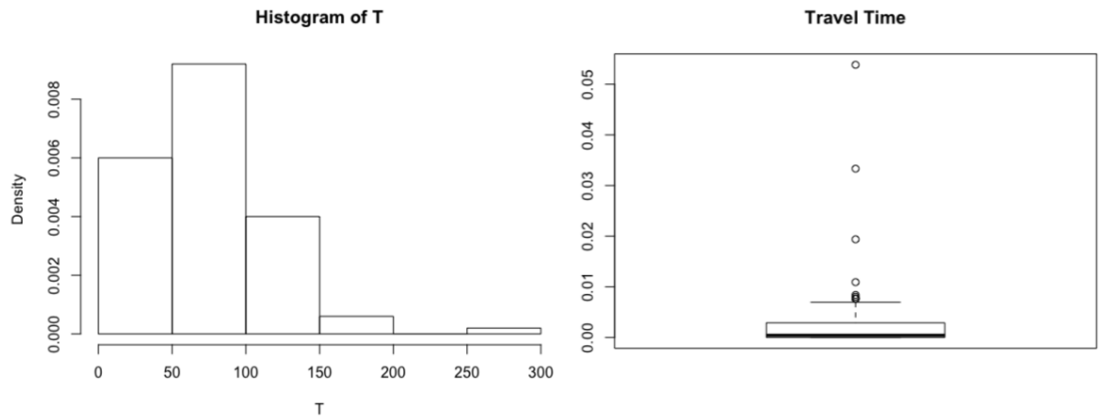

Figure 5. Descriptive statistics of travel time

For Housing Price (P), the median and mean housing prices are around 36,000 and 44,000 Yuan/square meter. Three quarters of the complexes have the housing prices of less than 61,000 Yuan/square meter.

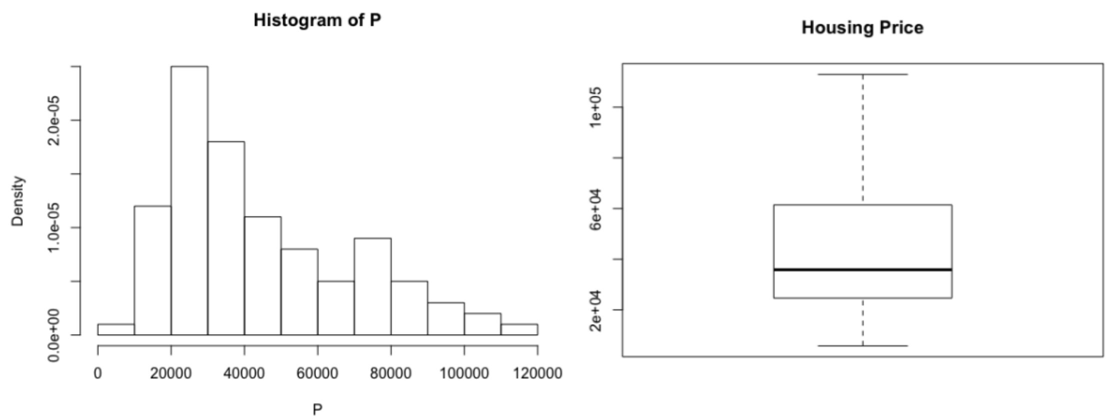

Figure 6. Descriptive statistics of housing price

However, housing price is quite varied with a minimum of 6,000 Yuan/square meter and a maximum of 113,000 Yuan /square meter. The distribution of housing prices is not normal distribution because the kurtosis is -0.19 and skewness is 0.86.

5.2 Regression and hypothesis testing on Accessibility Index

5.2.1 Power analysis

In the thesis, I select the alpha (significance level) of 0.05 and the power of 0.8. It is a convention to set the level at 0.05 and the power of 0.8, which is also proper for the thesis. It is calculated that the mean Accessibility Index (AI) for affordable housing complexes is 0.00035, and the mean AI for commercial housing complexes is 0.00489. also, the standard deviations for affordable and commercial housing complexes are 0.00076 and 0.00898 respectively. Therefore, the effect size (d) in Power Analysis should be 0.71, which is (0.00489-0.00035)/ (Sqrt (0.00076^2+ 0.00898^2)/2).

Table 5. Mean and standard deviation of Accessibility Index

Accessibility Index	Mean	Standard deviation
Affordable housing complexes	0.00035	0.00076
Commercial housing complexes	0.00489	0.00898

From the power calculation of Inferential Statistic, test results show that the effective sample size is at least 43. Therefore, the sample size of 50 for each of the population is sufficient for the study.

From the power calculation of regression, the result shows that v is at least 48. Therefore, the effective sample size is at least v + u +1 = 48 +4 +1, that is 53. So, the sample size for regression, which is 100, is sufficient for the study.

In conclude, the sample sizes of 50 for Inferential Statistics and 100 for

Regression Analysis are both sufficient for the study with the power of 0.8 and significance level of 0.05.

Table 6. Summary of sample size and power analysis

Power Analysis	Sufficient sample size	Selected sample size	Result
Inferential Statistic	43 each group	50 each group	Sufficient
Regression	53	100	Sufficient

5.2.2 Hypothesis testing

With the same samples in regression analysis, the study uses a “two sample t-test” to test the hypothesis. The null hypothesis is that affordable housing complexes has a higher Accessibility Index then commercial housing complexes.

From the Inferential Statistics analysis, the results show that p-value < 0.001. Therefore, we are 99% confident to reject the Null hypothesis that affordable housing and commercial housing have the same accessibility to metro stations. So, one of the research questions can be answered that commercial housing complexes have better the metro accessibility than affordable housing complexes.

5.2.3 Regression analysis

Model selection

From the effect plots we can see that Housing Price (P) has significant positive relation with Accessibility Index (A). it is also significant that affordable housing (H) has lower Accessibility Index than commercial housing. Long travel time (T) to city center with public transportation leads to a lower Accessibility Index as well. However, built year (Y) of a residential complex does not have significant relation with Accessibility Index. Besides, these graphs show the distribution and standard error of each independent variable.

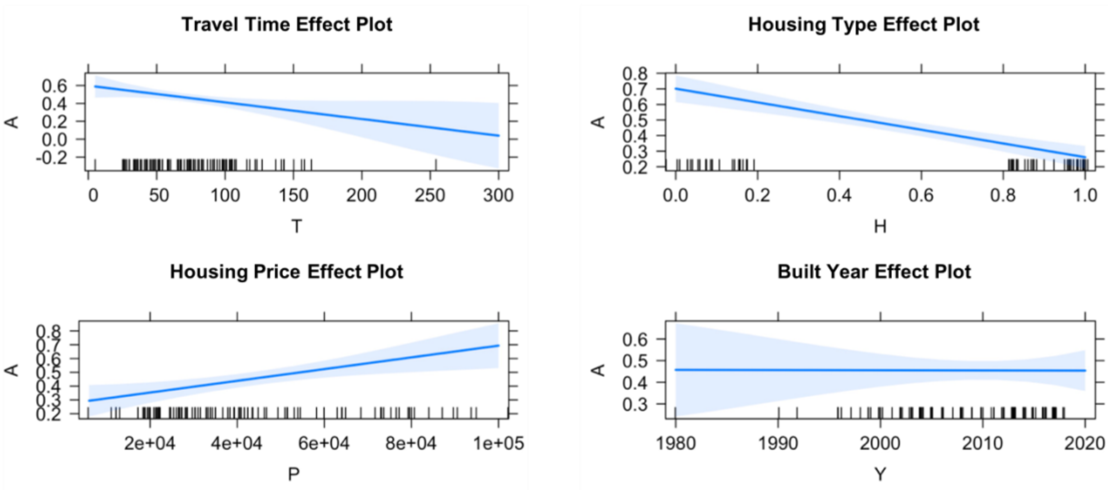

Figure 7. Results of effect plots

In the regression, different models have been tested to choose the most suitable model. From the Correlation Table we can see that the selected variables do not have the problem of collinearity.

Table 7. Correlation of variables

	Housing Type	Accessibility	Built Year	Travel Time	Housing Price
Housing Type	1.00	-0.82	0.63	0.66	-0.72
Accessibility	-0.82	1.00	-0.57	-0.71	0.76
Built Year	0.63	-0.57	1.00	0.50	-0.56
Travel Time	0.66	-0.71	0.50	1.00	-0.73
Housing Price	-0.72	0.76	-0.56	-0.73	1.00

Regression equation

Since the have the standard error, t-value, and P>|t| for each regression coefficient. These tell us how much the dependent variable changes for a unit change in the independent variable. We can use these to write out the equation:

*A = 0.6587 – 1.865e-03 * Travel time - 4.404e-01 * Housing type + 4.247e-06* Housing price -8.060e-05* Built Year*

Regression interpretation

Table 8. Significant levels of regression model

Multiple R-squared	0.759	F-statistic	100.7
Adjusted R-squared	0.71	P-value	<2.2e-16

Table 9. Significant levels and estimates of variables

	Estimate	P-value	Significant Level
Intercept	6.59e-01	1.74e-07	***
Travel time	-1.87e-03	0.024	*
Housing type	-0.40e-01	2.52e-10	***
Housing price	4.25e-06	0.0027	**
Built Year	-8.06e-05	0.08	-

Note: 0 '***', 0.001, '**', 0.01 '*'.

For F statistics & Statistical significance, the regression model has 3 predictors. Thus, we have 3 degrees of freedom for the model. F (3, 96) = 100.7. The F of 100.7 is the ratio of the mean square for the model to the mean square for the residual. Prob > F = 0.0000. This here, we say that F (3, 96) = 100.7, $p < 0.001$. There is a highly significant relationship between Accessibility Index and the set of 3 predictors.

For R^2, we can see that the regression model explains 75.9% of the variance in number of Accessibility Index. Because the R-squared is greater than 0.3, we have a strong relationship.

The slope of Housing Price (P) is significant at the significance level of 0.001; the slope of Housing Type (H) is significant at the significance level of 0; the slope of Travel Time (T) is significant at the significance level of 0.01.

For each additional 10,000 Yuan/ square meter of Housing Price, the Accessibility Index will have an increase of 0.425, controlling the other two factors. Compare with affordable housing, commercial housing can increase the Accessibility Index will by 0.404, controlling the other two factors.

5.3 Observation of the quality of accessibility

5.3.1 The selection of observations

Table 10. Attributes of paired observation complexes

	Observation	Type	Accessibility	Travel Time	Housing Price
High accessibility	A	Affordable	0.004	52	58220
	D	Commercial	0.004	35	76499
Mean accessibility	B	Affordable	0.00045	92	28535
	E	Commercial	0.00045	74	39301
Low accessibility	C	Affordable	0.00025	103	25387
	F	Commercial	0.00026	100	38323

The highest Accessibility Index of affordable housing complexes is 0.004, which is Lane 1329 Hutai Road (Observation A). To pair with the affordable housing sample, a commercial housing sample with the same Accessibility Index is chosen, which is Lane 118 Xietu Road (Observation D). Except the same Accessibility Index, Observation D also has some other similarities with Observation A than commercial housing complexes.

The average Accessibility Index of affordable housing complexes is 0.0004, and the chosen sample is Lan 200 Jiaan Road (Observation B) with an Accessibility Index of 0.00045. To pair with the affordable housing sample, a commercial housing sample with the same Accessibility Index is chosen, which is Lane 75 West Chuangxin Rd (Observation E). Except the same Accessibility Index, Observation E also has some other similarities with Observation B than commercial housing complexes.

The lowest Accessibility Index of affordable housing complexes is 0.00025, which is Lane 1358 North Yunhe Road (Observation C). To pair with the affordable housing sample, a commercial housing sample with a similar Accessibility Index is chosen, which is Lane 538 NO.157 Fuyuan Rd (Observation F). Except the same Accessibility Index, Observation F also has some other similarities with Observation C than commercial housing complexes.

5.3.2 Calculation of accessibility quality

Typically, stations with high POI values can provide job, shopping and recreation opportunities to people. The higher Accessibility Quality a metro station has, the easier it is for people to get from that metro station to points of interest (POI).

For the pair of high Accessibility Index observations, though the observations have the same Accessibility Index, the commercial housing complex has a higher quality of metro accessibility than the affordable housing complex. It takes 29 minutes and 7 metro stations to travel from Observation A to the nearest station with high POI value, which is the Jinan Temple Station. In contrast, it takes 21 minutes and only one metro station to travel from Observation D to the nearest station with high POI value, which is the Expo Museum Station.

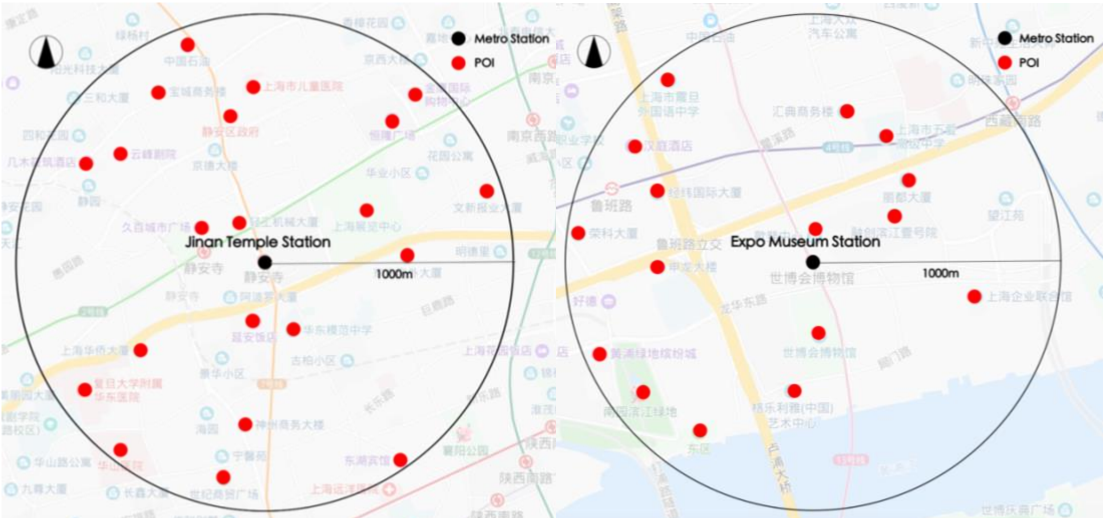

Figure 8. POI around Observation A and Observation D

For the pair of mean Accessibility Index observations, though the observations have the same Accessibility Index, the commercial housing complex has a higher quality of metro accessibility than the affordable housing complex.

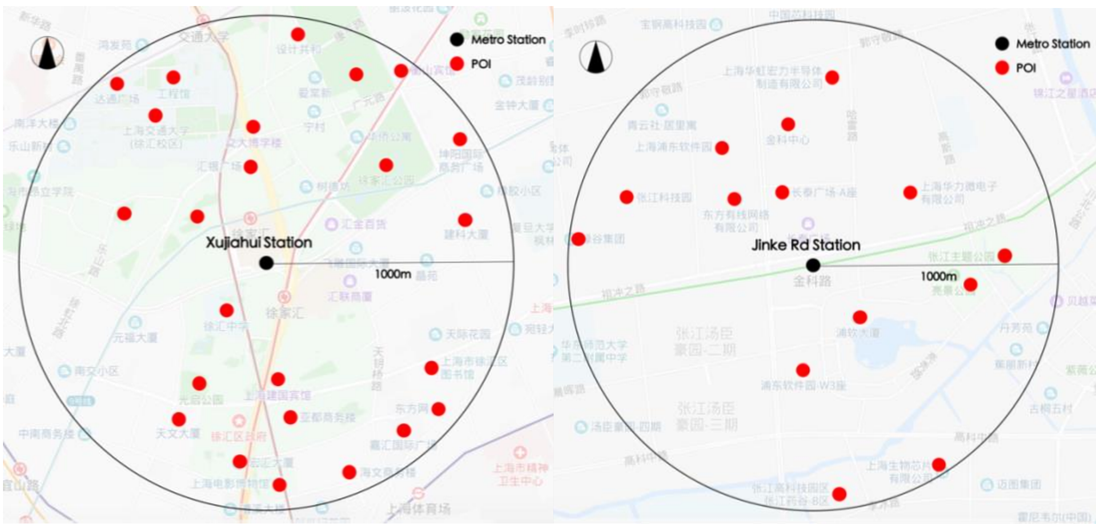

Figure 9. POI around Observation B and Observation E

It takes 73 minutes and 16 metro stations to travel from Observation B to the nearest station with high POI value, which is the Xujiahui Station. In contrast, it only takes 37 minutes and 2 metro stations to travel from Observation E to the nearest station with high POI value, which is the Jinke Road Station.

For the pair of low Accessibility Index observations, though the observations have the same Accessibility Index, the commercial housing complex has a higher quality of metro accessibility than the affordable housing complex. It takes 65 minutes and 10 metro stations to travel from Observation C to the nearest station with high POI value. In contrast, it only takes 40 minutes and 3 metro stations to travel from Observation F to the nearest station with high POI value.

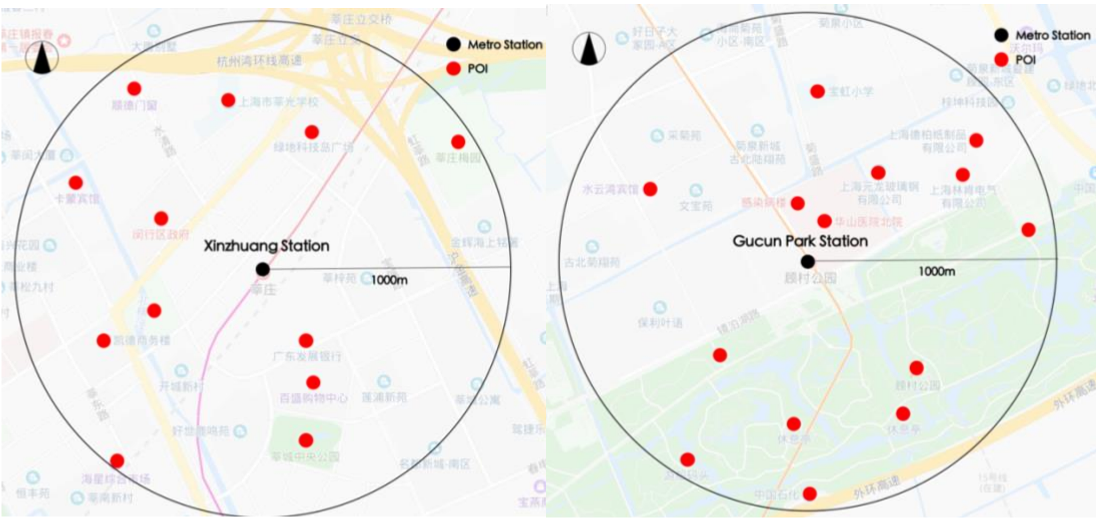

Figure 10. POI around Observation C and Observation F

5.3.3 Findings

For the three pairs of observations, commercial complex observations have higher accessibility quality. They are much closer to the station with many points of interest (POI) than affordable complex observations. We can see from the table that whatever accessibility is, it takes less than 40 minutes and 3 stations to travel from commercial complex observations to a nearest station with high POI value. However, it takes 11 stations on average to travel from affordable complex observations to a nearest station with high POI value.

Besides, although Accessibility Index analysis and Accessibility Quality analysis are two different factors, the observations of higher Accessibility Indexes often have a better accessibility quality.

Table 11. Comparisons of accessibility quality of complexes

	Observation	Type	Time (minute)	Number of Stations
High accessibility	A	Affordable	29	7
	D	Commercial	21	1
Mean accessibility	B	Affordable	73	16
	E	Commercial	37	2
Low accessibility	C	Affordable	65	10
	F	Commercial	40	3

5.4 Summary of findings

According to the descriptive statistics, commercial housing complexes have more metro stations and lines within a 2,000-meter walking distance than affordable ones. On average, commercial housing complexes have 2.32 metro lines, which is almost 6 times of that of affordable ones. From hypothesis testing, we can conclude that commercial housing complexes have a higher Accessibility Index than that of affordable housing complexes.

The regression model is significant and can explain 76% of the variance in Accessibility Index. The regression equation is: A = 0.6587 – 1.865e-03 * Travel time-4.404e-01 * Housing type + 4.247e-06* Housing price-8.060e-05* Built Year, where all the independent variables are significant. For each additional increase of 10,000 Yuan/ square meter of Housing Price, the Accessibility Index will increase by 0.425. For each additional 10 minutes of traveling from a residential complex to the city center with public transportation, the Accessibility Index will decrease by 0.019. Compare with affordable housing, commercial housing can increase the Accessibility Index by 0.404.

From the observation, we can conclude that commercial complex observations have higher accessibility quality. For the three pairs of observations, commercial complex observations are much closer to the station with many points of interest (POI).

Chapter 6. Conclusions and recommendations

6.1 Conclusions

The study shows that most affordable housing complexes in Shanghai have remote location and poor metro accessibility compared to commercial ones, leading to high transportation costs for affordable housing residents and high vacant rate of affordable housing.

For the first research question, we can conclude that most affordable housing built after 2008 has not followed the regulation. It is worth noting that 40 of 47 affordable housing complexes are not within a distance of 20 minutes' walk from metro stations, let alone the radius of 15 minutes' walk in the regulation.

For the second research question, hypothesis testing and regression results show that commercial housing complexes have better accessibility to metro than affordable housing complexes, in both quantity and quality. Within a radius of 20 minutes' walk, the number of metro lines around commercial housing complexes is six times higher than affordable housing complexes on average. Besides, the observation shows that commercial complexes have higher quality of accessibility, with metro stations more accessible to POI.

For the third research question, we can conclude from the regression results that housing type is a significant factor of metro accessibility. The effect of replacing affordable housing with commercial one is equal to raising the housing price by 9505 yuan/ square meter, with all other factors controlled.

6.2 Recommendations

6.2.1 Combining transportation and affordable housing planning

It cannot be judged whether the location of affordable housing leads to the lower metro accessibility or a lower metro accessibility leads to the location of affordable housing. However, it is certain that the planning department did not consider much about public transportation in the planning of affordable housing. Every year the Shanghai government starts a large number of affordable housing projects to accomplish the affordable housing plan. For example, Shanghai plans to build 60,000 affordable housing units in 2019 (Eastern Network, 2019). However, many affordable housing projects are not well planned in the aspects of location, transportation, and supporting facilities (Ding, 2014). For lack of public transportation and supporting facilities, many built affordable housing units are vacant. According to the study by Ding (2014), more than 60% of 52 affordable housing complexes in his study have a vacancy rate of 20%. Therefore, the planning department should combine the planning of public transportation and large-scale affordable housing projects.

I would recommend the government to strongly enforce the 2008 regulation that affordable housing should be built within a 15-minute walk to metro stations. The housing department and transportation department should make a joint effort in the planning stage to realize the regulation. Besides, the housing department should not only focus on accomplishing the number of affordable housing units, but also improving the public transportation around affordable housing complexes.

6.2.2 Creating more POI in the suburban area

The quality of accessibility cannot be neglected, which means that proximity to metro stations is not the only focus. The study shows that even if affordable housing has the same proximity to metro stations as commercial housing, it takes many more stations to get to areas with many points of interest (POI). Therefore, it is also important to create more points of interest in suburban areas of Shanghai, especially in city subcenters. Currently, it takes affordable housing residents much longer time than commercial housing residents to travel to points of interest. However, if there are more well-developed subcenters in the suburban area, affordable housing resident can have a better accessibility to job, shopping and recreation with metro. With a better job-housing balance, it is conducive to easing the traffic pressure between suburban and urban areas and reducing traffic costs of affordable housing residents.

6.2.3 Connecting suburban areas with metro

Currently, most metro lines in Shanghai are extending from the city center to different directions of the suburban area. Although it is quite convenient to travel from suburban to city center with metro, the main problem is that there are no efficient connections between affordable housing developments in the suburban and job opportunities in city subcenters. However, Shanghai Metro is now gradually changing to solve this problem. One example is that Metro Line 9 connects Songjiang New Town and Caohejing Development Zone, a large-scale affordable housing development and a large industry zone. I would recommend the transportation department to connect more affordable housing developments and city subcenters in the suburban area when planning new metro lines.

6.3 Limitations of the study

First of all, the study only considers local accessibility between two types of accessibility because of the limited data and research time. In the future, the thesis could be improved by adding the analysis of network accessibility, which considers the locations of metro stations in the public transportation system. Secondly, there are only 100 samples in the study. Although the sample size is sufficient to conduct the study, having more samples could improve the accuracy of the study. Additionally, the analysis of observation could be improved by having more supporting theories to make it more reasonable to readers.

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